

Appendix H: Economic Impacts of Deer on Forests

Description of Resource.

Some research has been conducted on the effects that the white-tailed deer can have on forest vegetation. Very little research has been conducted or survey information collected concerning the economic impacts to the forest landowner. The forest landowner may be economically impacted by white-tailed deer, depending upon their goals and objectives for the land. Wisconsin has approximately 14.7 million acres of commercial forest land with an additional 700,000 acres of reserved or non-productive commercial forest land (Spencer *et al.* 1988). The forest landowners in the state of Wisconsin vary greatly, as do their reasons and responsibilities for owning the land. For the purpose of this section, the discussion and analysis will focus on the potential economic impacts of deer on desirable forest trees for commercial forest landowners. Commercial forest land is defined as forest land producing or capable of producing crops of industrial wood and not dedicated to another use (typically land that is capable of producing 20 cubic feet of wood/acre/year).

Evidence of Effects.

Economic impacts of deer on forest vegetation focus primarily on the foraging of plants, although antler rubbing on high value forest "crops" such as Christmas trees can have significant economic impacts (Jones 1984). Significance of forage effects for any landowner would depend upon many variables including their specific land ownership goals and objectives, the forage period (time of year or season), the deer population or concentration foraging the area, and the sensitivity of a plant species to forage including the rarity of the foraged species. It should be noted that although deer forage on seeds (mast) produced by trees, especially in those medium to good oak acorn- producing years (Pils *et al.* 1981), the impacts of this forage are not known. For example, Hartvigsen (1988) reported in a Connecticut study that consumption of chestnut oak (*Quercus prinus*) acorns significantly reduced the number of oak seedlings produced at one site, however, this reduction did not appear to influence tree species composition.

There is evidence found in research documenting site specific examples of deer impacts on forest vegetation. In Wisconsin, these impacts may be especially profound where and when deer yarding occurs. For this assessment, site-specific evidence of deer impacts on forest regeneration will be discussed. However, it must be recognized that these site-specific examples do not necessarily reflect an average condition for a larger spatial scale. Research on deer impacts on forest regeneration for individual tree species has been conducted at a larger scale, for example multi-county studies on seedling and sapling development in eastern hemlock (*Tsuga canadensis*) (Beals and Cottam 1967; Frelich and Lorimer 1985, Alverson *et al.* 1988; and Anderson and Katz 1992). Trends identified by this research suggest that hemlock regeneration is declining due to deer browse; however, Mladenoff and Stearns (1993) suggest that a combination of landscape level interactions (climate, disturbance, hemlock life history, ecosystem processes, and historic land use) may better describe these forest regeneration trends. Research quantifying the impacts of deer relative to the various landscape impacts on hemlock or other forest regeneration is not available.

The effects of deer on desirable forest vegetation for a specific site can be detrimental and can create economic losses. Deer can have dramatic effects on vegetation by browsing foliage, terminal and lateral buds and young shoots of trees. Mortality or loss of vigor to trees caused by heavy deer browse can be an economic deterrent to artificial regeneration efforts such as planting trees in certain areas. An example of this impact is in Jackson County (Hess 1991) where economic loss in jack pine (*Pinus banksiana*) and red pine (*Pinus resinosa*) plantations has been attributed to deer herbivory. Overwinter deer populations for these areas were targeted and subsequently estimated by the Department of Natural Resources (DNR) at 25-30 deer per square mile. After timber harvest, seedlings planted in 15 plantations between 1987 and 1991 on 1,452 acres in the Jackson

County Forest were surveyed for deer browse. Significant losses in 1987-88 in the pine plantations were attributed to drought, but additional losses were correlated to the impact of deer. The report concluded that deer damage accounted for a loss of \$23,000 per year within that 5-year tree planting effort totaling \$140,470.

Several Pennsylvania studies also discussed concerns over deer herbivory on the natural regeneration of forests. Tilghman (1989) studied the impact of deer at five different population levels at approximately 1, 10, 20, 40, and 80 deer per square mile. Forest regeneration was negatively impacted both in growth and desired diversity with increasing deer populations. Tilghman (1989) recommended that a population of 18 deer per square mile would ensure tree regeneration and desired species composition for these Pennsylvania sites. An earlier regeneration study in 9-22 year-old clearcuts of a variety of hardwoods (Marquis 1981) documented that deer browse resulted in a variety of economic losses including: inadequate tree stocking, a delay in the establishment of natural regeneration, and less valuable tree species composition. This study says that deer populations during the clearcut establishment were approximately 25 deer per square mile; however, the populations rose to 36-39 deer per square mile during the 1970s suggesting that the higher populations of deer certainly had a negative impact and inferring that populations of 25 deer per square mile may have been detrimental to regeneration at these study sites. Marquis (1981) projected that timber values can be greatly impacted by deer. With a number of stated assumptions, Marquis provided examples where non-fenced stands were projected to lose approximately 50% of their value as compared to the protected, fenced stands.

The statewide impact of white-tailed deer on forest landowners is unknown. Based on the information available, a cumulative approach to assessing the impact of deer on forest landowners and desirable vegetation has not been done.

The next portion of this section will discuss the general forest land ownership using the Statewide Forest Inventory and Analysis (FIA) data and the effects of High, Medium, and Low deer populations on the large forest landowners within the various deer management regions using available research and qualitative information obtained from landowners.

Northern Forest Region.

The Northern Forest Region covers 11,530,600 acres or approximately 32% of the state. Forests cover approximately 71% or 8,227,100 acres of this region. This forest acreage represents approximately 54% of the state's total forest land.

Based on the limited information available, the literature cited studied the effects of deer primarily in forested areas. The effects of high deer populations (>20 deer per square mile) may contribute to a decrease of certain species, the mortality of certain valued species, or the loss in vigor and subsequent value of tree species that may be desirable to landowners. This impact can create a potential economic loss to landowners. It must be noted that some of the literature cited may be more applicable to the transitional forest/agriculture matrix found to the south of the Northern Forest.

The Northern Forest has large public ownerships, large industrial ownerships and many private ownerships. Based on discussions with several large landowners and managers, concerns were generally limited for specific sites where the targeted deer population was greater than 25 deer per square mile and a high-valued forest crop was managed. High-valued crops included plantations and Christmas trees. In areas of deer yarding, many concerns were expressed over natural and artificial regeneration, however, these comments were also very localized. For example, where high-valued Christmas trees were grown, deer damage has been measured by the landowner, and at times these landowners resorted to fencing the land, creating an economic cost.

Medium to Low populations (<20 deer per square mile) of deer in the Northern Forest do not appear to significantly impact desirable commercial forest vegetation and the associated economics for landowners.

Central Forest, Western Farmland, and Eastern Farmland Regions.

The analyses for the Central Forest, Western Farmland, and Eastern Farmland Regions are grouped, because this area represents a transitional land use between forest in the north and agriculture to the south. Background information is first being provided followed by the grouped analysis. Analysis are the same concerning how deer may impact the forest landowner although it must be noted that the large forest ownerships decrease in these regions, especially in the Western Farmland.

Central Forest Region. The Central Forest Region covers 2,893,200 acres or approximately eight percent of the state. Forests cover approximately 48% or 1,394,200 acres of this region. This forest acreage represents approximately nine percent of the state's total forest land.

Western Farmland Region. The Western Farmland Region covers 5,580,900 acres or approximately 16% of the state. Forests cover approximately 33% or 1,857,700 acres of this region. This forest acreage represents approximately 12% of the state's total forest land.

Eastern Farmland Region. The Eastern Farmland Region covers 6,215,800 acres or approximately 17% of the state. Forests cover approximately 33% or 2,081,000 acres of this region. This forest acreage represents approximately 14% of the state's total forest land.

Based on the limited information available, the literature cited studied the impacts of deer primarily in forested areas. The effects of High deer populations (>30 deer per square mile), and at times Medium deer populations (16-29 deer per square mile), may contribute to a decrease in value of forest land desirable to landowners. The decrease of these tree species may create a potential economic loss to landowners. The concern over Medium deer populations (25 deer per square mile) was expressed several times by large landowners in these regions, especially where the Eastern and Western Farmland transitioned to the Northern Forest Region. Increased economic losses were discussed in the Eastern and Western Farmland regions with density goals at 25 deer per square mile vs. little reported economic loss in contiguous Northern Forest DMU's with density goals at 20 deer per square mile. Land manager's concerns were usually limited to specific sites where the deer population goal for that DMU was at least 25 deer per square mile and a high-valued forest crop was managed. High-valued crops included forest plantations and Christmas trees. An example of this concern was in Burnett County where 1-3 year old jack pine plantations were heavily browsed (Western Farmland) as compared to similar plantations with less detrimental browse (Northern Forest). The deer population goals were 25 deer per square mile (actual populations estimated at 27.33 deer per square mile) and 20 deer per square mile (actual populations estimated at 23.67 deer per square mile) over the last three years. Landowners didn't express concerns over deer yarding in this region.

Another example of concern associated with a high-value crop in these regions is the planting of red oak seedlings (*Quercus rubra*). Where animal herbivory is a concern, including deer browse associated with high populations, the use of plastic tubes over red oak seedlings has been prescribed by foresters for protection against animal browse. Plastic tubes can represent a significant cost.

Low populations (<16 deer per square mile) of deer in these regions do not appear to significantly impact desirable forest vegetation and the associated economics for landowners. One large tribal land manager commented that deer densities estimated between 7-12 deer per square mile had no significant impacts on forest regeneration.

Southern Farmland Region.

The Southern Farmland Deer Management Region totals 9,717,300 acres or approximately 27% of the state. Forests cover approximately 18% or 1,791,300 acres of this region. This forest acreage represents approximately 12% of the state's total forest land.

In the Southern Farmland, there is very little information available concerning the impacts of deer on forest landowners. The acreage of forest land greatly decreases in the south as do the large land ownerships. The impacts of deer on forest landowners for any particular forest site may be similar to the relative impacts of High, Medium, and Low deer population densities found elsewhere in Wisconsin, however, the total impact would be much less due to the decreased amounts of forest land.

All Regions.

The economic impacts of white-tailed deer to the commercial forest landowner, and more specifically to the forest industry, certainly changes from northern to southern Wisconsin. Part of this change is due to the fact that the amount of forest land in the state decreases steadily from north to south as do the number of landowners. The large public and industrial ownerships found in the north and central portions of the state are not represented in the south, where the ownership is primarily small, private landowners. Because of this ownership pattern, the direct foraging impacts of deer to forested property is greater in the northern, central and western regions.

Summary.

Very little research has been conducted or survey information collected concerning the economic effects of deer on the forest landowner. The actual economic impact is not well studied, and additional surveys and research would be necessary to estimate actual values lost due to deer foraging. The forest landowner may be economically impacted by white-tailed deer, depending upon their goals and objectives for the land. Economic impacts of deer on forest vegetation focus primarily on the foraging of high value forest "crops" such as Christmas tree or fiber plantations. There is evidence documenting site-specific examples of negative economic deer impacts on planted forest vegetation. Several Pennsylvania studies also raised concerns over deer herbivory on the natural regeneration of forests. Generally, economic concerns resulted in these research efforts where deer populations exceeded 25 deer per square mile. In personal communication with large public or industrial ownerships, concerns over deer forage were expressed where populations exceeded 25 deer per square mile, and at yarding sites.

Wisconsin has approximately 14.7 million acres of commercial forest land. The potential economic impact of deer for each deer management region relates directly to the amount of commercial forest land in the region. Generally, the potential impact decreases from northern Wisconsin to southern Wisconsin. The acreage and percent forest coverage within each region is as follows: Northern Forest Region - 8,227,100 acres (71%), Central Forest - 1,394,200 acres (48%), Western Farmland - 1,857,700 acres (33%), Eastern Farmland - 2,081,000 acres (33%), and Southern Farmland - 1,791,300 acres (18%).

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Appendix I: Vehicle-Deer Collisions

The data presented in this appendix were provided for a regional analysis of vehicle-deer collisions, the data is based on data gathered in 1994.

Description Of Resource.

In some regions of Wisconsin, where habitats can support over 80 deer per square mile, overwinter population goals are primarily determined by human tolerance. Vehicle-deer collisions are a primary factor in determining just how many deer people will accept.

Accurate counts of total vehicle-deer collisions are not possible, because not all deer carcasses are located and removed from the roads. Some deer continue to travel after being struck and later die away from the road. Others cause little property damage and accident reports are not filed to the Department of Transportation. However, the Department of Natural Resources (DNR) records of carcass disposal provides an estimate of the minimum number of deer hit by vehicles and should approximate trends in the number of vehicle-deer collisions.

Since 1985, Wisconsin motorists have reported an average of almost 36,000 vehicle-deer collisions per year (unpublished). Recent studies indicate that actual figures may be more than double reported figures (unpublished). Costs of property damage and personal injury resulting from vehicle-deer collisions in Wisconsin were estimated at \$92 million per year (Hall 1991).

Evidence of Effects.

Vehicle-deer collisions throughout the state have steadily increased during recent years. A definite trend has emerged, indicating a relationship between both numbers of deer hit and overall deer population, as well as numbers of miles driven. Research has shown that the number of vehicle-deer collisions is dependent on both the deer density and the overall volume of traffic (McCaffery 1973b). As deer densities increase, the number of vehicle-deer collisions will increase as well, even when traffic volume remains constant. Likewise, when traffic volume increases and deer densities remain constant, vehicle-deer collisions will increase. Decreases in deer density will result in fewer deer hit by vehicles, assuming traffic volume remains constant.

Risk of vehicle-deer collisions has not been reduced by whistles, roadside reflectors, or fencing (Ford and Villa 1993; Dalton and Stanger 1990; Romin and Dalton 1992). The only known way to efficiently reduce deer collision hazards, without reducing traffic, is by reducing deer numbers.

Areas with high human populations and travel often have the highest incidence of vehicle-deer collisions. For example, counties surrounding the Madison, Milwaukee, and Green Bay metropolitan areas have some of the highest frequency of vehicle-deer collisions in the state each year (1.0 vehicle-deer collision per square mile). These areas contain high levels of commuter traffic, which contribute to the high frequency of vehicle-deer collisions, and also have relatively high deer densities (25-35 deer per square mile) result in many deer-vehicle collisions. Wildlife professionals from the Ohio DNR consider deer goal reductions in similar situations when vehicle-deer collisions exceed 0.5 per square mile (Bob Stoll, Research Biologist, Ohio DNR, pers. comm.).

One 11-county area in South-Central Wisconsin makes up a region that has the highest overwinter deer density goals in the state - 30 or 35 deer per square mile of deer habitat. This area is primarily agricultural range with few major human travel corridors, so it has a significantly lower volume of vehicle traffic than the metropolitan areas previously mentioned. However, in terms of number of deer killed per square mile, this area experiences the highest level of vehicle-deer collisions in the state, leading to the conclusion that the high deer population in this area contributes significantly to high rates of vehicle-deer collisions.

Any increase in deer numbers is expected to result in higher numbers of vehicle-deer collisions, particularly considering that traffic volume is not likely to decline. Similarly, decreases in deer numbers would be expected to result in lower levels of vehicle-deer collisions.

Northern Forest.

Deer Management Unit (DMU) goals in this region range from 10 to 25 deer per square mile. This area also receives substantially lower levels of vehicle traffic compared to southern Wisconsin. As a result, fewer vehicle-deer collisions occur here when measured per square mile as well as actual numbers of reported accidents. However, low levels of vehicle-deer collisions are the result of low traffic volumes. If traffic volume were to increase in this region, vehicle-deer collisions would be expected to increase as well.

Central Forest.

Much of the area within this region typically sees more than 0.5 vehicle-deer collisions per square mile. Although no major human travel areas fall within this region, two of its boundaries are major highways (I 90-94 and Hwy. 51). With deer goals ranging from 25 to 30 deer per square mile, vehicle-deer collisions would be expected to rise with any increase in overall deer numbers.

Western Farmlands.

Deer population goals range from 15 to 25 deer per square mile in this region. Most counties average between 0.5 and one vehicle-deer collisions per square mile. This region also contains several major highway systems, and receives high levels of commuter traffic in the counties east of Minneapolis - St. Paul, Minnesota.

Eastern Farmlands.

The combination of high deer population goals (ranging from 20 to 30 deer per square mile) and high levels of commuter traffic results in much of this region having a vehicle-deer collisions rate of more than 1.0 per square mile. The entire region experiences a minimum of 0.5 vehicle-deer collisions per square mile.

Southern Farmlands.

In this region, DMU goals range from 10 to 35 deer per square mile of range, and vehicle-deer collisions range from less than 0.5 to over 1 per square mile. Western counties have the lowest incidence of vehicle-deer collisions with few major highways and lower human density, and deer goals ranging from 15 to 25 deer per square mile. Central counties, primarily centering around I-90/94 and the Madison metropolitan area, have deer density goals of 30-35 deer per square mile; more than one vehicle-deer collisions per square mile occur. East-central counties have deer density goals of 10-30 deer per square mile, but have considerably lower volumes of traffic than counties to the east or west, and therefore, vehicle-deer collisions decrease to between 0.5 and 1 per square mile. Finally, the far eastern counties in the Milwaukee metropolitan area, with deer density goals of just 10-20 deer per square mile have a high incidence of vehicle-deer collisions due to high traffic volume.

Summary.

Vehicle-deer collisions have negative impacts on motorists in Wisconsin, resulting in millions of dollars in personal and property damage each year. Increases in deer densities, increases in traffic volume, or both will result in more vehicle-deer collisions. Decreasing deer population goals would be expected to result in reductions in vehicle-deer collisions. Areas of high deer population goals and human vehicle traffic typically experience the highest levels of collisions. The only efficient method of reducing vehicle-deer collisions without reducing the number of miles traveled is to reduce deer numbers.

Vehicle-deer collisions per square mile are generally lowest in those DMUs where deer population goals are less than 25 deer per square mile and traffic volume is low. Such areas typically lie in the Northern Forest region, as well as being scattered throughout other areas of the state. Areas of highest concern are primarily in farmland regions where deer goals equal or exceed 25 deer per square mile, and in metropolitan areas with high traffic volumes. Major travel corridors, such as interstate highways, also have high instances of vehicle-deer collisions.

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Appendix J: Baiting and Feeding Background – DRAFT 2-05-03

Background.

Deer baiting is the deliberate placement of food items for the purpose of attracting or habituating deer to a location for the purpose of hunting. Deer feeding activity includes recreational, supplemental, and emergency feeding. Feeding does not include the placement of food and attractants for the purpose of hunting deer. Recreational feeding is done mainly for the purpose of viewing deer. Supplemental feeding normally involves placing larger quantities of food or mineral to augment naturally occurring foods. The purpose may be to attract, concentrate, and hold deer on specific parcels of land or to locally increase carrying capacity for deer and/or antler development. Emergency feeding has involved the deliberate placement of food during unusually severe winters, mainly to mitigate winter losses of deer. References to feeding in this document refer to all forms of feeding unless specified otherwise.

Baiting.

Baiting of deer for hunting purposes had been legal in Wisconsin until 2002. But, historic prohibitions on using bait for waterfowl and use of salt for attracting deer may have fostered widespread belief that baiting of deer was illegal. Despite this, low levels of baiting existed in northern areas that had very low deer densities. Growing awareness that baiting was legal led to a rather sudden and widespread increase in baiting during the 1980s and 1990s.

Michigan biologists first documented the magnitude of baiting. A 1984 survey found that Michigan hunters placed 3.3 million bushels of bait at a time when most hunters still believed that baiting was illegal (Langenau *et al.* 1985). Only seven years later, this amount had increased to 13.1 million bushels (Mich. DNR 1992).

Recent surveys of Wisconsin hunters found that relatively few (13%-16%, Borgerding 1993; 16%, Dhuey and McCaffery 1999, Dhuey 2001) firearm hunters reportedly used bait. The proportion of archers using bait continues to increase as about a third (34%) of archers used bait in 1997 (Dhuey 1998). The proportion increased to 40% in 2001 (Dhuey 2002, Wisconsin DNR 2002). A survey in 1992 found that most (53% to 66% depending on issue) hunters recognized some problems with baiting and only 32% were in favor of allowing baiting for both gun and bow hunting. However, fewer than half favored a baiting ban in all hunting seasons (Petchenik 1993). Disease concerns were not addressed in this survey. Hunter concerns focused mainly on deer behavior and hunting ethics.

Feeding.

Prior to the discovery of CWD in Wisconsin, feeding of deer by the public had not been regulated in the state. Recreational feeding of deer by some rural resorts, restaurants, taverns and residents have had a long tradition of putting food outside of windows to provide close-up viewing of deer. The proportion of Wisconsin's rural residents that feed deer has not been determined, but recent concern for disease transmission in the upper Midwest has forced reexamination of these practices.

Both government agencies and private individuals have provided supplemental food to deer. Private individuals have traditionally been mostly landowner-hunters who wished to increase deer numbers on their properties. The number of private supplemental feeders in Wisconsin has only been locally estimated (Wisconsin Department of Natural Resources unpubl. data), but has likely increased as more rural land has been acquired for residential and recreational uses.

The United States Fish and Wildlife Service has long fed elk at the National Elk Refuge in Wyoming. However, the current Refuge manager has built strong arguments against continuing the practice (Smith 2001). Many state resource agencies have a history of supplemental feeding of deer. For the most part, this occurred prior to the establishment of biologically defensible deer population goals. Wisconsin actively fed deer from the mid-1930s to the mid-1950s with a peak effort in 1950-51 when 1,131 tons were provided (Dahlberg and Guettinger 1956:183). Supplemental feeding and emergency feeding became blurred during this period as deer populations were being maintained at very high levels and winter losses were common. Biologists argued against feeding very early in

these programs, (Bartlett 1938 in Michigan; Leopold 1943 in Wisconsin). For the most part supplemental feeding by agencies ended with the advent of better scientific data.

In 1961, Congress enacted Public Law 87-152 authorizing use of surplus grains for alleviating emergency conditions for wildlife. However by 1971, Michigan found it necessary to prohibit use of surplus corn for feeding deer based on “serious nutritional problems,” deer management factors, and costs (Arnold 1971).

Public opinion during the severe winter of 1983-84 urged Wisconsin DNR to undertake emergency feeding. Reasons for not providing emergency feed included: 1) only a proportion of the distressed deer could be accessed for feeding; 2) of those with access, not all would be saved by feeding; and 3) the expected cost would have approached \$120 per deer saved (Miller 1986). With a buck-only hunt expected the following year (less than 10% of herd harvested), the cost per deer added to the hunter’s bag was expected to be about \$1,200. Still higher costs were reported or implied in later years by Baker and Hobbs (1985) in Colorado and Lenarz (1991) in Minnesota. In Minnesota, only three percent more deer survived in the northern forest region during 1989 than if no “emergency” feeding had been done (Minnesota DNR 1989).

Lacking authority to regulate feeding, the Wisconsin DNR recognized the growing interest in private “emergency” feeding of deer during severe winters. A policy was established to provide technical advice on when, what, where, and how to feed deer during severe winters. This policy did not encourage deer feeding but offered guidance to citizens who chose to feed deer. It discouraged use of corn and hay, and was designed to minimize harmful effects of feeding (Wisconsin DNR 1996). This policy, however, did not address disease concerns. There is broad consensus among deer managers in northern states that feeding should not occur except under extreme circumstances. Colorado reported that “feeding has potential to reduce or prevent game damage and reduce winter mortality, but feeding is not a panacea and has potentially dangerous side effects” (Colorado DNR 1984a).

Historically, circumstances that might justify feeding have ranged from a predicted 30% loss of adult female deer (Colorado DNR 1984b) to local extirpation (Goulden 1983). The greatest proportion of deer killed by malnutrition in northern Wisconsin during the past 40+ years was in 1971 when winter mortality may have approached 30% (Kohn 1975). Adult does, which are the productive part of the herd, normally comprise only a small proportion of winter losses (Dahlberg and Guettinger 1956, Kubisiak, *et al.* 2001; Van Deelen *et al.* 1997) as adult females carry more stored fat into winter (McCaffery 1988). Furthermore, occasional winter losses are normal and natural near the northern limit of white-tailed deer range.

The Wisconsin DNR was recently authorized by the Legislature to regulate deer feeding beginning in 2002 in response to controlling CWD (Wisconsin Act 108, Appendix A). This authorization expires on June 30, 2004. This legislation resulted in the passing an emergency administrative rule prohibiting baiting and feeding of deer beginning July 2002. The Joint Committee for Review of Administrative Rules authorized the extension of this emergency rule until April 1, 2003. Any rule on deer feeding will expire June 30, 2004 unless current authority is extended by the Legislature.

Baiting and Feeding in Relation to Disease.

Researchers who have studied CWD epidemics in both captive and free-ranging deer populations have determined that CWD is both contagious and self-sustaining (meaning that new infections occur fast enough for CWD to persist or increase over time despite the more rapid deaths of the diseased individuals; Miller *et al.* 1998, 2000). Supporting evidence comes from observational data (Williams and Young 1992; Miller *et al.* 1998, 2000) experimental data and epidemiological models fit to observed prevalences in free-living deer (Miller *et al.* 2000, Gross and Miller 2001, M. W. Miller unpublished cited in Williams *et al.* 2002).

Research indicated that deer can get CWD by eating something contaminated with the disease prion. (Sigurdson *et al.* 1999). Other non-familial TSEs (Kuru, transmissible mink encephalopathy, bovine spongiform encephalopathy[BSE]) appear to be transmitted through ingestion of prion-infected tissue as well (Weissmann *et al.* 2002). In part because of the human health crisis associated with eating BSE-infected beef in Europe, many other researchers working with transmissible spongiform encephalopathies (TSEs) including CWD (Sigurdson *et al.* 1999, 2001) have traced the movements of infectious prions of orally-infected animals through the lymph tissue embedded in the intestinal mucosa, into nervous tissues communicating with the digestive tract (*e.g.* Maignien *et*

al 1999, Beekes and McBride 2000, Heggebo *et al.* 2000, Huang *et al.* 2002) and eventually to the brain via the nervous system (Sigurdson *et al.* 2001, Weissmann *et al.* 2002). Experimental studies using hamsters have shown that TSE prions can infect through minor wounds in the skin (Taylor *et al.* 1996). Moreover prion infection of hamsters through minor wounds on the tongue was much more efficient than infection from ingestion (Bartz *et al.* 2003). These researchers not only demonstrate that an oral route of infection is possible, they are working toward detailed knowledge of the physiological pathways that convey infectious prions into the nervous system and other organs (Weissmann *et al.* 2002).

Following oral exposure, infectious prions associated with many TSEs (Maignien *et al.* 1999, Huang *et al.* 2002) including CWD (Sigurdson *et al.* 1999, Miller and Williams 2002, Spraker *et al.* 2002b) both accumulate and replicate in the lymph tissues associated with the gastrointestinal tract -notably, in lymph tissues in contact with the mucosa lining the inner wall of the intestines (*e.g.* Peyer's patches, Weissmann *et al.* 2002). In infected deer, CWD prions also accumulate in the pancreas and various glands of the endocrine system (Sigurdson *et al.* 2001). Experiments with hamsters demonstrated that infectious prions can travel from the brain to the tongue along tongue-associated cranial nerves (Bartz *et al.* 2003). During digestion, the liver, pancreas, intestinal mucosa, and other glands secrete chemicals needed for digestion (Robbins 1983) and cells lining the inner surface of the intestine continuously die and slough off providing potential physical mechanisms for prion shedding into the intestines (others are likely). This is evidence that infectious prions are shed in the feces and saliva (Sigurdson *et al.* 1999).

Disease course and symptoms indicate high potential for contamination of food where deer are concentrated. Appearance of CWD symptoms in an infected deer lags initial exposure by a variable time period on the order of roughly 12-24 months or more ([E. S. Williams and M. W. Miller unpublished; E. S. Williams, M. W. Miller, and T. J. Kreeger unpubl.] cited in Williams *et al.* 2002). Once clinical symptoms start, deer enter a symptomatic phase that may last on average 1-4 months before they invariably die (Williams *et al.* 2002). Symptoms are subtle early on but eventually may include behaviors likely to contaminate a site with bodily fluids (*e.g.* excess urination, excess salivation including drooling and slobbering, and uncontrollable regurgitation, Williams *et al.* 2002). The fact that deposition of feces increases with concentration of deer activity is both obvious and intuitive and pellet group counts have been used as an index of deer density since the 1940's (Bennet *et al.* 1940). During winter, northern deer defecate about 22 times a day (Rogers 1987). At least one study (Shaked *et al.* 2001) has reported detection of an altered form of the infectious prion in the urines of hamsters, cattle, and humans with TSEs. This altered form, while not as virulent, was capable of producing sub-clinical or carrier-state prion infections following experimental inoculation. Shedding of infectious prions is likely progressive during the course of disease from infection to death (Williams *et al.* 2002). Replication and presence of infectious prions in gut-associated lymph tissue early in the incubation (Sigurdson *et al.* 1999, Weissmann *et al.* 2002) and epidemiological modeling (M. W. Miller unpubl. cited in Williams *et al.* 2002) suggest that shedding precedes the onset of symptoms in both elk and mule deer.

In this regard, Garner (2001) documented a particularly alarming behavior among deer using frozen feed piles. Deer used the heat from their mouths and nostrils to dislodge food such that frozen feed piles were dented with burrows made from deer noses. He reported that "Throughout the winter multiple numbers of deer were observed working in and around the same feed piles. I suspect that each deer that feeds this way at a frozen feed pile leaves much of its own saliva and nasal droppings in the field pile at which its working" (Garner 2001, p. 46).

In addition to direct lateral transmission, deer can be infected indirectly from contaminated environments and contaminated pastures "appear to have served as sources in some CWD epidemics (Miller *et al.* 1998, [M. W. Miller unpublished and E. S. Williams, W. E. Cook, and T. J. Kreeger unpubl.] cited in Williams *et al.* 2002). The potential for transmission from the environment is likely a function of the degree of contamination and the resistance of disease prions to chemical breakdown (Williams *et al.* 2001, 2002a). Consequently, the highest prevalences recorded for CWD outbreaks have been in captive situations (Williams and Young 1980, Williams *et al.* 2002) where because of abnormal concentration, indirect and direct transmission likely occur together (Williams *et al.* 2002). At high concentration, the persistence of the CWD prion in contaminated environments, may be a serious obstacle to disease eradication (Williams *et al.* 2002).

People use baiting and feeding to concentrate deer for enhanced hunter opportunity or viewing. Provision of artificial food sources encourages unnatural congregation of animals, thereby increasing contact and enhancing the transmission of infectious agents (Barlow 1996). In northern deer, seasonal concentration in deeryards is a well-known phenomenon (Blouch 1984). Artificial feeding interferes with the natural process of yarding and to the extent it does, it is undesirable (Ozoga and Verme 1982). A ban on baiting and feeding would allow deer to return to natural yarding behaviors in severe winters. However, the potential for fine scale contact over a feed pile is fundamentally different than the fine scale contact that yarded deer would get while foraging on natural food. In deeryards, deer eat a variety of woody browse plants and arboreal lichens (Blouch 1984) scattered across a large area. In terms of biomass and nutrition, the best source of browse and lichens may be litter-fall rather than live plant material growing in the understory (Ditchkoff and Servello 1998). Food sources in deer yards (litter and understory plants) are widely distributed over a large area and they are not replaced. Moreover, browse is typically held aloft on the plant stem such that fecal contamination is less likely. Foraging by wintering deer is an optimization process. Energy gains associated with eating need to be balanced against energy costs associated with travel and exposure (Moen 1976). Yarded deer with little or no access to supplemental food maintain relatively large overlapping home ranges (e.g. 110 acres in Minnesota [Nelson and Mech 1981], 480 acres in Michigan [Van Deelen 1995], 318 acres in Quebec [Lesage *et al.* 2000]) suggesting that foraging widely on a diffuse food source is normal. Garner (2001) monitored 160 radio-collared deer for 2 fall/winter periods in northern Michigan and documented their behavior over feeding sites using both telemetry and direct observations. He demonstrated that, relative to natural forage, supplemental feeding caused reduced home range sizes, increased overlap of home ranges in space and time and dramatic concentrations of activity around feeding sites. Similarly, Kilpatrick and Stober (2002) indicated that the provision of food increased animal contacts by focusing their activity.

Reduction of contact through a ban on baiting and feeding is disproportionately important to eradicating or containing a CWD outbreak. Epidemiological models fit to real-world data on CWD outbreaks in mule deer predict that local extinction of infected deer populations is likely (Gross and Miller 2001). The predicted outcomes of these models are highly sensitive to input estimates of the amount of contact between infected and susceptible deer meaning that small reductions in contact rates can dramatically reduce the rate at which prevalence changes during an epidemic (Gross and Miller 2001). Garner (2001) demonstrated that baiting and feeding was associated with deer concentration, extensive face-to-face contacts, and increasing overlap of deer home ranges. White-tailed deer have social contacts apart from contact over baiting and feeding sites (Marchinton and Hirth 1984) but social groups tend to be small relative to other deer species and both their physiology and behavior are adapted to selective foraging on nutritious plants (Putman 1988). Moreover, social groups tend to exclude one another (Mathews 1989), thus eliminating the additional direct and indirect contact that occur between groups using baiting and feeding sites (Garner 2001) eliminates a large amount of group-to-group contact that would otherwise occur.

Eliminating these contacts has added significance because CWD is a uniquely difficult disease to manage. There is no treatment and no vaccine. Moreover CWD is difficult to track in a population because of long incubation periods, subtle early clinical sign, a resistant infectious agent, potential for environmental contamination and incomplete understanding of transmission mechanisms. These characteristics make prevention critically important (Williams *et al.* 2002). Hence, An international panel reviewing CWD management in Colorado emphasized that, "Regulations preventing ... feeding and baiting of cervids should be continued" (Peterson *et al.* 2002).

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